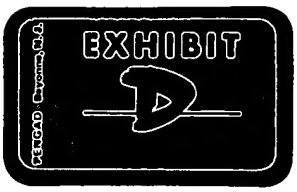

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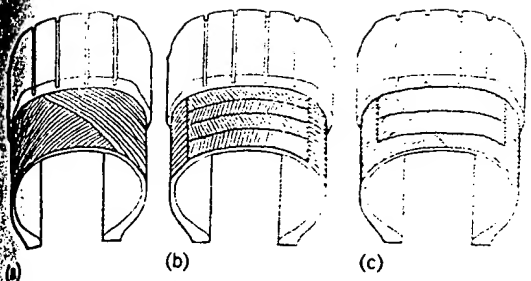

Tire construction. (a) Bias-ply. (b) Radial. (c) Belted bias. (Goodyear Tire and Rubber Co.)

the stresses within the tire body, the vulcanization changes the rubber compound into a tough, highly elastic material and bonds the parts of a tire into one integral unit. When the tire emerges from the curing press, the building process is complete.

Types. There are three types of tires: bias-ply, radial, and belted bias (see **illus.**). For bias tires, cords in the plies extend diagonally across the tire from bead to bead. The cords run in opposite directions in each successive ply, resulting in a crisscross pattern. For radial tires, cords in the plies extend transversely from bead to bead, substantially perpendicular to the direction of travel. Belts are placed circumferentially around the tire. For belted bias tires, plies are placed in a manner similar to that used in the bias-ply tire, with belts of material placed circumferentially around the tire between the plies and the tread rubber.

Developments. Although most tire improvements appear gradually, a number of important developments have marked great advancements.

Fabric. Rayon was introduced in the late 1930s as a replacement for cotton. Nylon followed in the late 1940s, and it remains the basic material in truck, earthmover, and aircraft tires. Polyester, combining the best features of rayon and nylon, was first used in auto tires in the early 1960s; it became the most used tire cord and is in virtually all auto tires.

Tubeless tires. Prior to the mid-1950s all tires had to have inner tubes to contain the air pressure. The development of the tubeless tire brought increased puncture resistance and less heat buildup.

Belted tires. The belted bias tire was developed in the late 1960s to increase tread life and tire performance. Then in the 1970s the radial tire, long popular in Europe, won acceptance in the United States and became the most popular form of auto tire construction. Fiber glass, steel, and finally aramid were developed as materials for the belts.

Rubber. Early tires were totally dependent on natural rubber, which was often poor in quality. During World War II synthetic rubber was developed and now accounts for about 80% of the rubber used by the tire industry. Other compounds have allowed for greatly improved traction on ice, even without metal studs. Compound development also has led to lower rolling resistance, improved gasoline mileage, and longer tread life. *See* RUBBER.

David B. Harrison

Tissue

An aggregation of cells more or less similar morphologically and functionally. The animal body is composed of four primary tissues, namely, epithelium, connective tissue (including bone, cartilage, and blood), muscle, and nervous tissue. The process of differentiation and maturation of tissues is called histogenesis. *See* CONNECTIVE TISSUE; EPITHELIUM; PLANT TISSUE SYSTEMS.

Charles B. Curtin

Tissue culture

The branch of biology in which tissues or cells of higher animals and plants are grown artifically in a controlled environment. Such studies were undertaken in the hope that the behavior of various body components could be studied and their potentialities more readily analyzed under the simpler and more readily manipulated conditions possible in the test tube.

Study of the growth and interaction of animal cells with physical and chemical environments outside the body began about 1900. During the first decade it was demonstrated that cell multiplication from chick tissue transplanted into glass vessels could be maintained indefinitely, if suitable physical conditions for cell attachment to a solid substrate were provided, and if the necessary complex nutrient medium was replenished as fast as it was depleted by the cells' activities. From early, primitive beginnings, tissue culture has developed in many directions (**Fig. 1**).

Early methods of tissue culture were successful in promoting cell multiplication only when large numbers of cells were seeded together in a community. Growth of such large populations permitted many kinds of important experimentation on the multiplication process, but it also left many questions unsolved. For example, it was impossible to determine which fraction of the cells of any population had retained the ability to multiply. It also was difficult to determine the specific conditions which the individual cell requires in order to be able to initiate its reproductive process. A major advance along these lines was made by a group of scientists who succeeded in providing conditions permitting growth of single cells when individually sealed in capillary tubes. These cells were later grown into huge populations so that it was demonstrated that at least some cells which had originated in the mammalian body maintain their ability to multiply indefinitely in isolation, just like independent bacteria.

In early tissue culture, growth of cells was successful only when they were attached to a solid substrate like glass or cellophane. In 1954 it became possible to grow cells in liquid suspension as well, a technique that permits many new operations, such as continuous farming of cells in the same vessel for indefinite periods. In addition, it became possible to simplify greatly the medium required for cell multiplication so as to eliminate, at least in some cases, the need for animal serum. Definition of the chemical requirements for mammalian cell growth in test tubes proceeded in a variety of laboratories and reached the stage wherein massive populations can be grown for long periods in a completely molecularly defined medium. Single cells can be reliably grown into discrete colonies in a medium containing completely defined, small-molecular weight constituents and a purified protein fraction obtained from blood. The completely defined small-molecular weight constituents are salts, amino acids, glucose, choline and inositol, and the vitamins biotin, pantothenic acid, folic acid, niaci-

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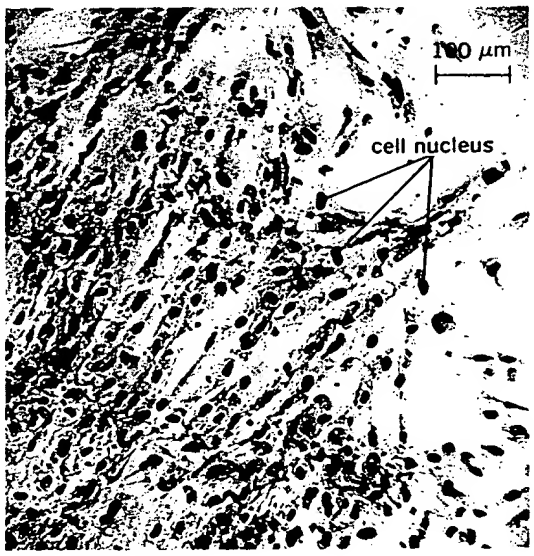
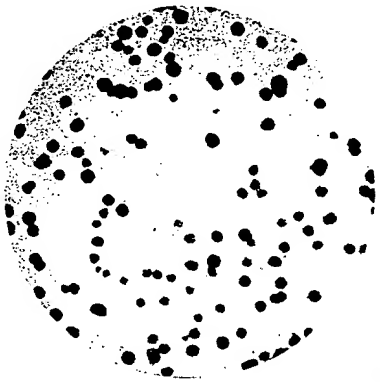


Fig. 1. Human spleen cells grown in a glass vessel containing a nutrient medium.

namide, pyridoxine, riboflavin, thiamine, and B_{12}. Such advances have been tremendously important in establishing the specific nutrient requirements for different types of mammalian cells, and for elucidation of the metabolic pathways taken by the different molecules, in both healthy and diseased subjects.



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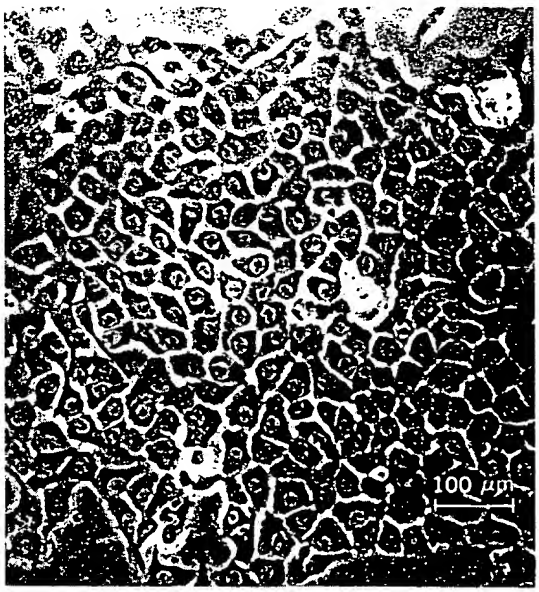

Fig. 2. Colonies developed from single human cancer (HeLa) cells. (*a*) Colonies grown on a glass dish. (*b*) Photomicrograph of a typical colony.

Quantitation. In research undertaken to permit quantitative measurement of cell growth, means were found by which animal cells grown in tissue culture could be dispersed singly, then added to a glass dish, under conditions wherein every single cell would reproduce in isolation to form a discrete colony (Fig. 2). This aim was, at first, successfully achieved for cancer cells and then was also achieved for cells from normal human and animal tissues. This method of "plating" single mammalian cells made possible many more precise kinds of experiments. The effects of different physical and chemical agents on growth of cells could now be measured with much greater accuracy, since the number of cells able to reproduce under the required conditions could be precisely determined by a simple colony count. It also became possible to measure accurately and conveniently the growth rate of such single cells in different media (Fig. 3).

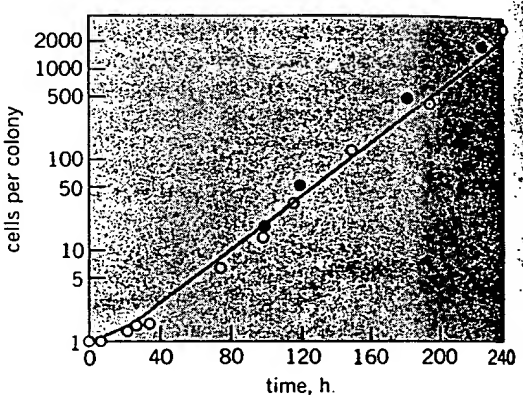

Fig. 3. Typical growth curve of single cells plated in a complete, nutrient medium. Cells begin to reproduce after initial delay of about 18 h and continue to double every 20 h as long as medium is not exhausted.

Study of hereditary mechanisms. Development of single-cell techniques afforded tissue-culture means for study of hereditary mechanisms in animal cells.

Cells grown in tissue culture by older techniques have demonstrated changes in their chromosome numbers and structures occurring with the passage of time. Since these bodies contain the genes which determine the hereditary potentialities of the cells, the genetic constitution of such cells was uncertain. Inferences drawn from the behavior of such cultures and then applied to interpretation of functions and potentialities of cells in the body, where chromosomal integrity is rarely altered, were often of doubtful significance. Various investigators then turned attention to these problems and developed new methods for study of the chromosomal constitution of mammalian cells in tissue culture.

One of the results of such advances in technique was the production of methods for regulating cell growth through extended periods of cultivation, so that the chromosomal integrity was maintained as reliably as it is in the body. It thus became possible to make many kinds of biochemical and genetic studies on such cells with considerably more confidence in the applicability of results to an understanding of cell functions in the intact animal.

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